

## **Analysis of South China Sea Shelf and Basin Acoustic Transmission Data**

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### **LONG-TERM GOALS**

My long-term research goals are: (1) The characterization, understanding, and prediction of the statistics (mean, variance and coherence) of low-frequency acoustic signals and ambient noise in the littoral zone. The signal statistics are primarily influenced by the ocean variability and bottom properties. The noise statistics are influenced by atmospheric forcing and shipping in addition to the ocean and bottom variability. (2) The development and improvement of inverse techniques for measuring the dynamics and kinematics of meso and finer-scale sound speed structure and ocean currents in coastal regions. (3) The understanding of three-dimensional sound propagation physics including horizontal refraction and azimuthal coupling and the quantification of the importance of these complex physics in the prediction of sound signals transmitted over highly variable littoral regions.

### **OBJECTIVES**

This is a three-year (2009-2011) project to complete the analysis of both the shelf and basin acoustic data collected from the Northeastern South China Sea (NE SCS) during the Windy Island Soliton Experiment (WISE). These data were collected between April 2005 and October 2006. The objectives of the basin acoustic data analysis are twofold: The first is to study and characterize the supertidal-to-seasonal-scale impacts of the transbasin nonlinear internal waves on long-range transmission loss. The second is to understand and quantify the variability of the observed ambient noise level in the basin. The second objective constitutes the primary focus of my data analysis effort in FY10.

### **APPROACH**

A hydrophone was moored at mid depth in the NE SCS basin from November 2005 to October 2006. Operated with a 1-min-on and 14-min-off duty cycle and sampled at 1.6 kHz, the measured time series captures the spectral characteristics and variability of the ambient noise in the 0-to-800 Hz band over an annual cycle. The relations between the observed noise levels and the relevant environmental variables are then examined using spectral estimation methods and scattered diagrams.

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## WORK COMPLETED

Using the measured acoustic data, the time-varying noise power spectral density was estimated at a 15-min interval over the annual cycle. From these spectral density estimates, time series of the noise spectrum levels and band levels were constructed. In order to gain insights into the predictability of the ambient noise field in this marginal sea, the interpretation of the noise levels was facilitated with the following environmental data:

1. Moored temperature time series, measured every 60 s or 90 s at various depths from May 2005 to Oct 2006.
2. Wind speed time series, from the US Navy Operational Global Atmospheric Prediction System (NOGAPS) surface wind analysis every 6-hours, interpolated to receiver location.
3. Precipitation time series, from the NOGAPS previous 12-hr precipitation accumulation fields, interpolated to receiver location.
4. Historical shipping density and vessel motion simulation, where the large commercial vessel density was based on 3-years of Lloyd's Ship Movement data, the fishing vessel density was from Food and Agriculture Organization (FAO) statistics, and the single vessel motion simulation was based on Lloyd's density and shipping lane structure.

## RESULTS

The characteristics and variability of the NE SCS ambient noise are depicted in Figures 1 and 2. Figure 1 allows for a visual comparison of the noise level time series at two different bands, lower (20-200 Hz) and higher (500-700 Hz), to the time series of in situ temperature change in the super-tidal band, wind speed and 12-hr cumulative precipitation over the duration of the experiment. Figure 2 illustrates the correlation (or the lack of) of the two noise band levels versus wind and precipitation using scatter plots.

In the lower frequency band (20-220 Hz), the NE SCS ambient noise is, not surprisingly, dominated by shipping. The ship noise shows a persistent variance through the year. The observed minimum noise level is what the Wenz curves refer to as "heavy shipping," implying that shipping over the NE SCS basin is heavier than the heavy shipping. Vessel motion simulations based on Lloyd's shipping density and lane structure was carried out to assess if the model could reproduce the observed noise level statistics. The finding is that the model simulations underestimate the observed levels, and investigation into the discrepancies is in progress. Two plausible sources of errors are that the historic shipping density database underestimates the number ships and that the source level models used is dated and requires modifications.

In the higher frequency band (500-700 Hz), the important findings include (i) the wind-dependent Wenz curves fit the observed levels well except at low wind speeds, a regime where ship noise dominates, (ii) heavier precipitation during summer monsoon appears to enhance the noise level, and (iii) mild correlation between noise level and precipitation can be visualized in the scatter plot when the 12-hr accumulated precipitation exceeds 3 mm.

Both the lower and higher band levels exhibit a 10-day rise-and-fall trend in mid March. This 10-day noise event was associated with a deep mesoscale cold feature that strengthened the sound channel.

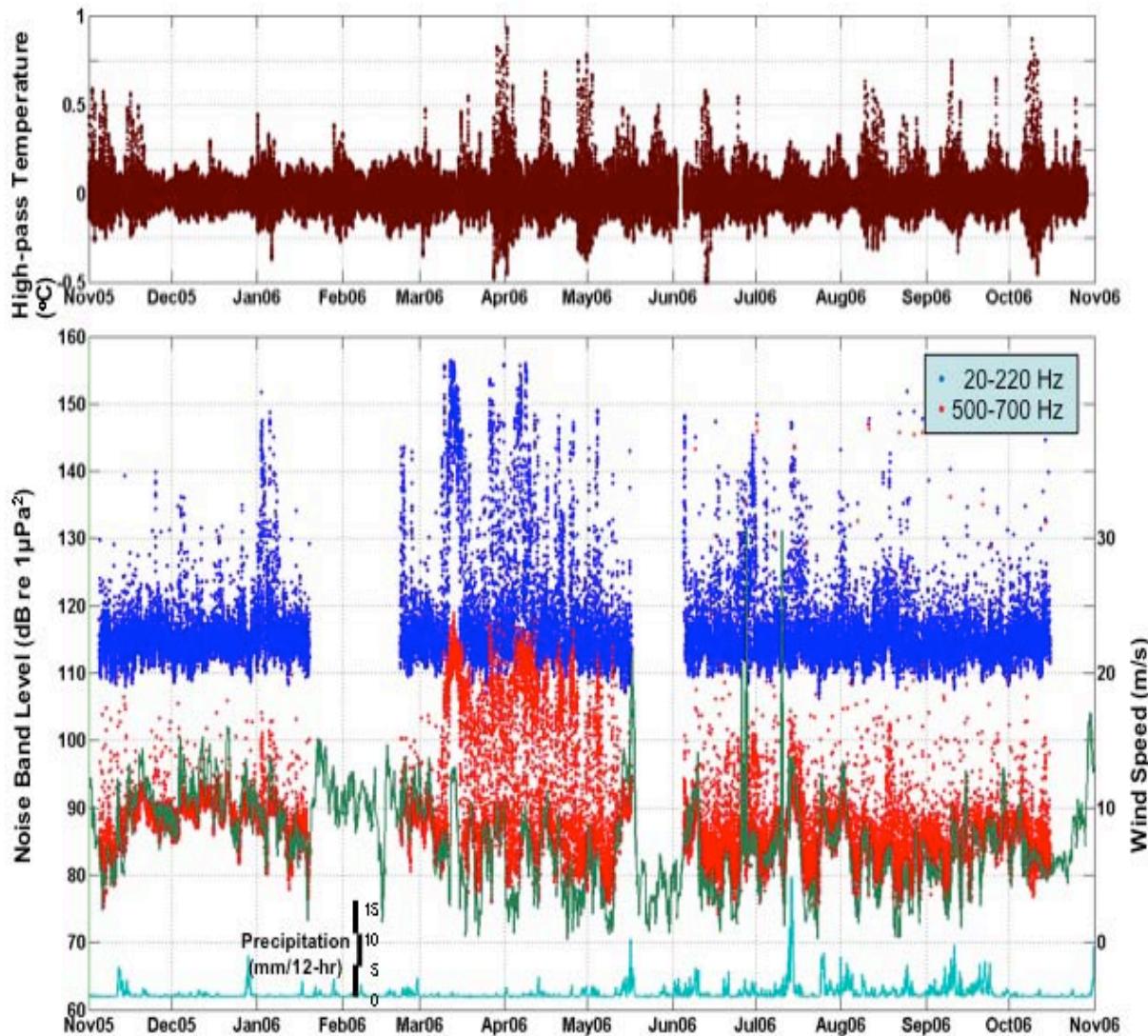
Modeling and validating the impact of this event on the noise level is in progress. Also, the frequent rises in noise level during spring, summer and fall are associated with the cross-basin nonlinear internal waves. However, it was a combination of true and mechanical noises. Elimination of data contaminated by mechanical noise is in progress.

## **IMPACT/APPLICATIONS**

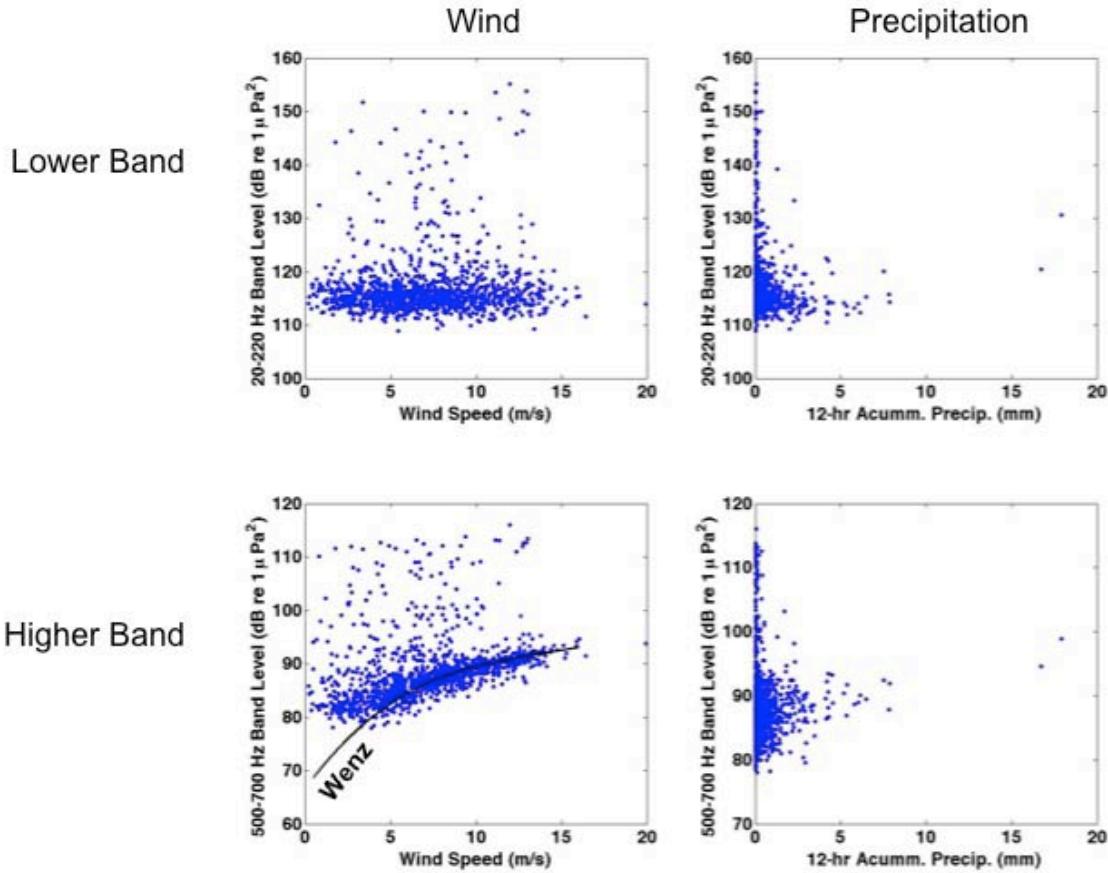
The oceanographic and acoustic data gathered in this field study should be valuable in helping to create models of shelfbreak regions suitable for assessing present and future Navy systems, acoustic as well as non-acoustic.

## **RELATED PROJECT**

This fully integrated acoustics and oceanography experiment should extend the findings and data from SWARM, Shelfbreak PRIMER, ASIAEX and SW06, thus improving our knowledge of the physics, variability, geographical dependence and predictability of sound propagation in a shelf-slope environment.



**Figure 1.** Observed time Series of noise band levels at two different bands, 20-220 Hz (blue) and 500-700 Hz (red), and their comparison to the time series of in situ temperature change at the super-tidal band (brown), wind speed (green) and 12-hr cumulative precipitation (cyan).



**Figure 2.** Scatter plots of noise band levels at two different bands, 20-220 Hz (top) and 500-700 Hz (bottom) versus wind speed (left) and precipitation (right).

## REFERENCE

Yang, Y. J., Y. C. Fang, M.-H. Chang, S. R. Ramp, C.-C. Kao, and T. Y. Tang (2009), Observations of second baroclinic mode internal solitary waves on the continental slope of the northern South China Sea, *J. Geophys. Res.*, **114**, C10003, 2009.

## PUBLICATION

Bernotavicius, C.S., Chiu, C.-S. (corresponding author), Miller, C.W., Reeder, D.B., Wei, R.-C., Yang, Y.-J., and Chiu, L., "Modeling a 400-Hz signal transmission through the South China Sea Basin," *J. Comput. Acoust.*, **18**(2), 193-208, 2010.

## HONORS/AWARDS/PRIZES

NPS Distinguished Professor Award, 2010.  
NPS GSEAS Extraordinary Merit Award for Entrepreneurialship, 2010.